Experiment 2: Recrystallization

Objectives

The purpose of this experiment is to show how organic compounds can be purified through the process of recrystallization. Techniques used in the experiment include hot gravity filtration and vacuum filtration. You will also learn more about the solubility of organic compounds and the use of activated charcoal. You will use the compound that you purify, acetanilide, in a subsequent experiment.

Introduction

When we prepare an organic compound, particularly one which may be destined for use in medicine, we obviously want that compound to be as pure as possible. Organic solids are usually purified by recrystallization (single- or two-solvent method). Single-solvent recrystallization involves dissolving the solid in the *minimum amount of a selected hot solvent*, rapidly filtering this hot solution to remove any insoluble impurities and then allowing the filtrate to *cool slowly* so that the desired compound comes out of solution in the form of large crystals. After cooling slowly to room temperature, the suspension of crystals in the mother liquor is chilled in ice water in order to maximize the amount of crystals formed. The crystals are collected in a Büchner funnel by suction filtration and then dried. If desired, the filtrate can be concentrated by boiling off some of the solvent to give a second crop of crystals.

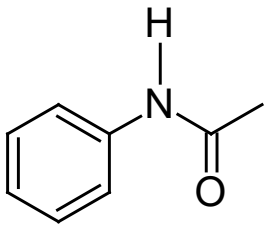
The two solvent method is only used if a suitable single solvent cannot be found. A pair of solvents is chosen: one in which the compound is soluble (called the "soluble solvent"), and one in which the compound is insoluble (called the "insoluble solvent"). The two solvents must be miscible in one another so that their solubility with one another does not limit the proportions used. This experiment will use the single solvent method.

In summary, single solvent recrystallizations require the following 5 steps:

1. Select the solvent (compound soluble in hot, insoluble in cold).
2. Dissolve in a **minimum** amount of hot solvent.

3. Hot gravity filtration, if solid impurities (particulates) are present. Add activated charcoal, if coloured impurities are present.
4. Slow cool to room temperature. Allow crystals to form. Then place crystals on ice.
5. Collect product by vacuum filtration. Save filtrate for possible second crop. Wash crystals with ice cold solvent and allow to air dry to a constant weight.

In this experiment you will recrystallize acetanilide using water as the solvent. Acetanilide is an aromatic amide, and its structure is shown below.



acetanilide

Purity and Solvent Selection

There are many reasons why we may need to recrystallize an organic solid compound. For instance, the compound may need a higher level of purity for use in an organic synthesis or for final characterization, especially if the compound is new or unknown. In medicine, an organic compound must be of very high purity before it can be administered to the body.

Measuring Purity

Purity can be determined in numerous ways such as infrared (IR) and nuclear magnetic resonance (NMR) spectroscopies, which we will use in later experiments. Another way to determine purity of a compound is by performing thin-layer chromatography (TLC), which will be learned in the next organic chemistry course (CHEM 360). As we learned in the previous experiment, one way we can simply determine if a compound is pure is to measure its melting point. A pure compound has a sharp and narrow melting point range, while an impure compound has a broad and depressed melting point.

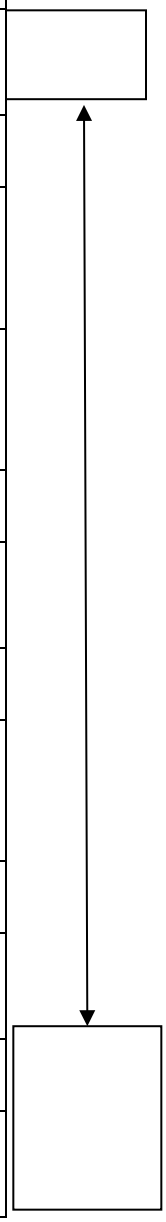
Selecting a Suitable Solvent

A suitable solvent should meet as many as possible of the following criteria:

- Have a boiling point in the 60-100 °C range, and this temperature should be lower than the melting point of the solid (to avoid 'oiling out').
- Have a freezing point well below room temperature, preferably below 4 °C.
- The solvent must not react with the solid compound being purified.
- Impurities should be highly soluble, or totally insoluble in the solvent.
- The solvent must not be excessively hazardous.
- 100 mL of the solvent should dissolve about 5 to 25 g of the solid when boiling and less than 2 g when cold, with at least a 5:1 ratio between the two values.

Common Recrystallization Solvent Properties

Solvent	bp (°C)	fp (°C)	Polarity * (20 °C)	Comment
Water	100	0	80.37	Solvent of choice for many 'polar' compounds, Disadvantage-crystals dry slowly.
Methanol	64	− 94	33.6	Good for relatively polar compounds, Advantage-easily removed.
95% Ethanol	78	− 116	24.3[25]	Excellent general solvent. Advantage-preferred over methanol i.e., higher bp. Disadvantage-contains 5% water.
Acetone	56	− 95	20.7	General purpose solvent for relatively polar cmpds. Disadvantage-low bp makes if difficult to work with.
2-butanone	80	− 86	18.5	Good general solvent. Advantage-higher bp than acetone.
Dichloromethane	40	− 95	9.08	General solvent for intermediate polarity compounds. Disadvantage-low bp, fairly hazardous
Ethyl acetate	77	− 84	6.02[25]	Good general solvent for intermediate polarity compounds.
Toluene	111	− 95	2.44	Good general solvent for aromatic compounds. Disadvantage-high bp makes it difficult to remove.
Petroleum ether	60-80	Low		Mixture of hydrocarbons, good for nonpolar cmpds.
Cyclohexane	81	6.5	2.02	Good general solvent for nonpolar compounds. Disadvantage-may freeze in ice bath.
Hexane	69	− 94	1.89	Good for nonpolar compounds, Advantage-easily removed.
Methylcyclohexane	101	− 127	NA	Good general solvent for nonpolar compounds. Disadvantage-high bp, volatile.



bp = boiling point at 760 torr, fp = freezing point, NA = not available.
* As indicated by the Dielectric Constant.

What solvent will dissolve a solid and how much will dissolve? These are very difficult and complex questions. A compound will generally dissolve in a given solvent, if the intermolecular forces (e.g., dipole-dipole interaction, hydrogen bonding, van der Waals) that hold its own molecules together are similar to the forces holding the molecules of the solvent together. The rule of thumb for

predicting solubilities is LIKE DISSOLVES LIKE. That is, polar solvents dissolve polar compounds quite well and nonpolar solvents dissolve non-polar compounds. For example, the nonpolar compound biphenyl (seen in Experiment 1) is very soluble in hexane but will not dissolve in water. Conversely, a polar compound like NaCl is very soluble in water but will not dissolve in hexane.